FAA Public Meeting – Proposed Cessna Wing Spar AD
3-4 March 2004 – Washington D.C.

Cessna
A Textron Company

Cessna Wing Spar Reinforcement

Beth Gamble

Cessna Aircraft Company

Cessna
A Textron Company

Introduction

Wing Spar Reinforcement

Cessna
A Textron Company

Wing Spar Reinforcement

- Cessna has issued mandatory service bulletins to install wing main spar reinforcement straps to assure continued airworthiness of Cessna's Model 400 series airplanes
- The wing spar reinforcement strap is the way to assure continued airworthiness without reliance on repetitive inspections

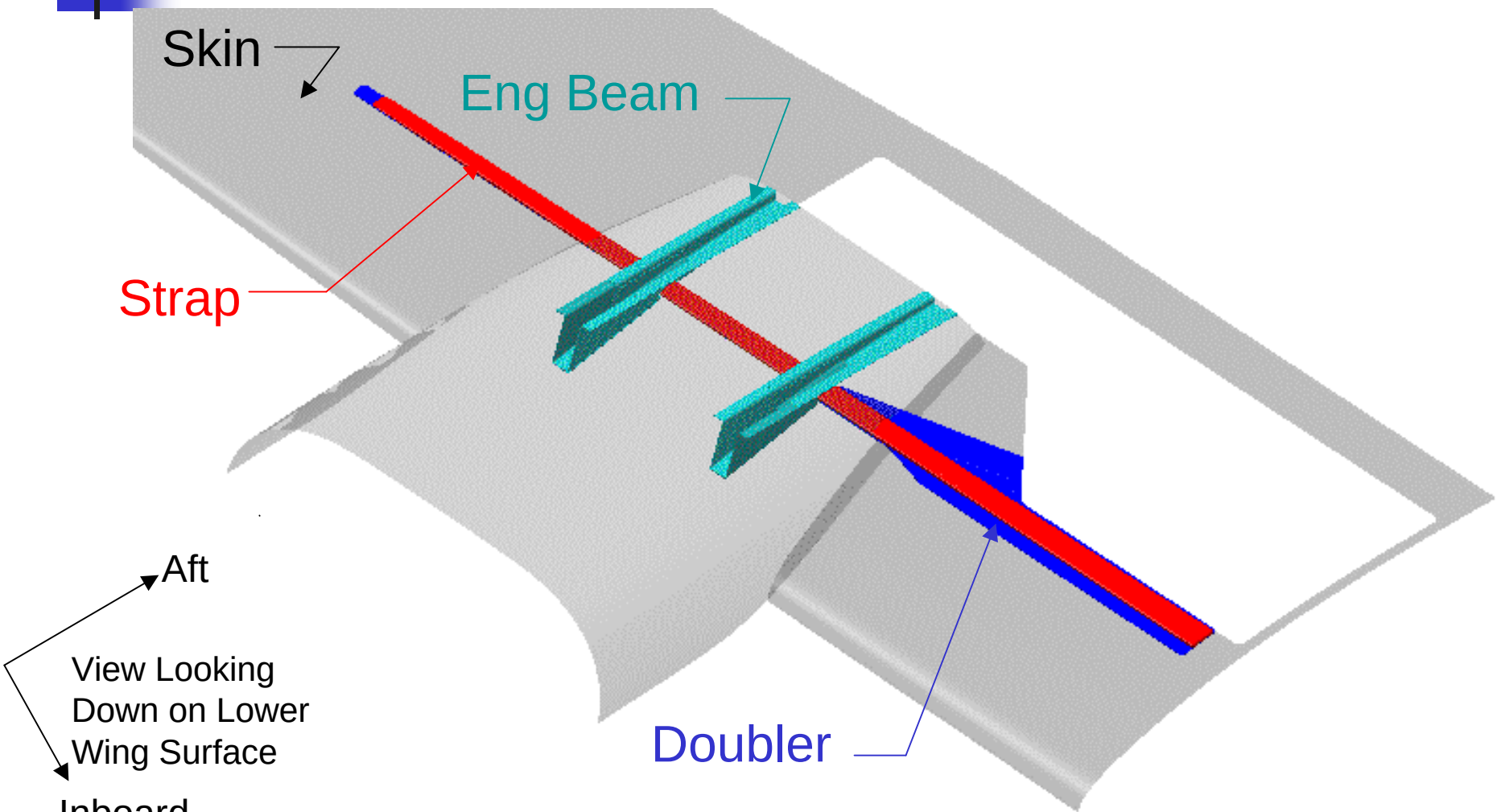
Cessna
A Textron Company

Installation Times

Model	Service Bulletin & Service Kit	Installation Time
401	MEB01-6 and SK402-46	6500 Flight Hours
402	MEB01-6 and SK402-46	6500 Flight Hours
402C	MEB02-5 and SK402-47	15000 Flight Hours
411	MEB01-7 and SK411-59	5500 Flight Hours
414A	MEB02-5 and SK402-47	9000 Flight Hours (Units 1-200) 15000 Flight Hours (Units 201 & On)

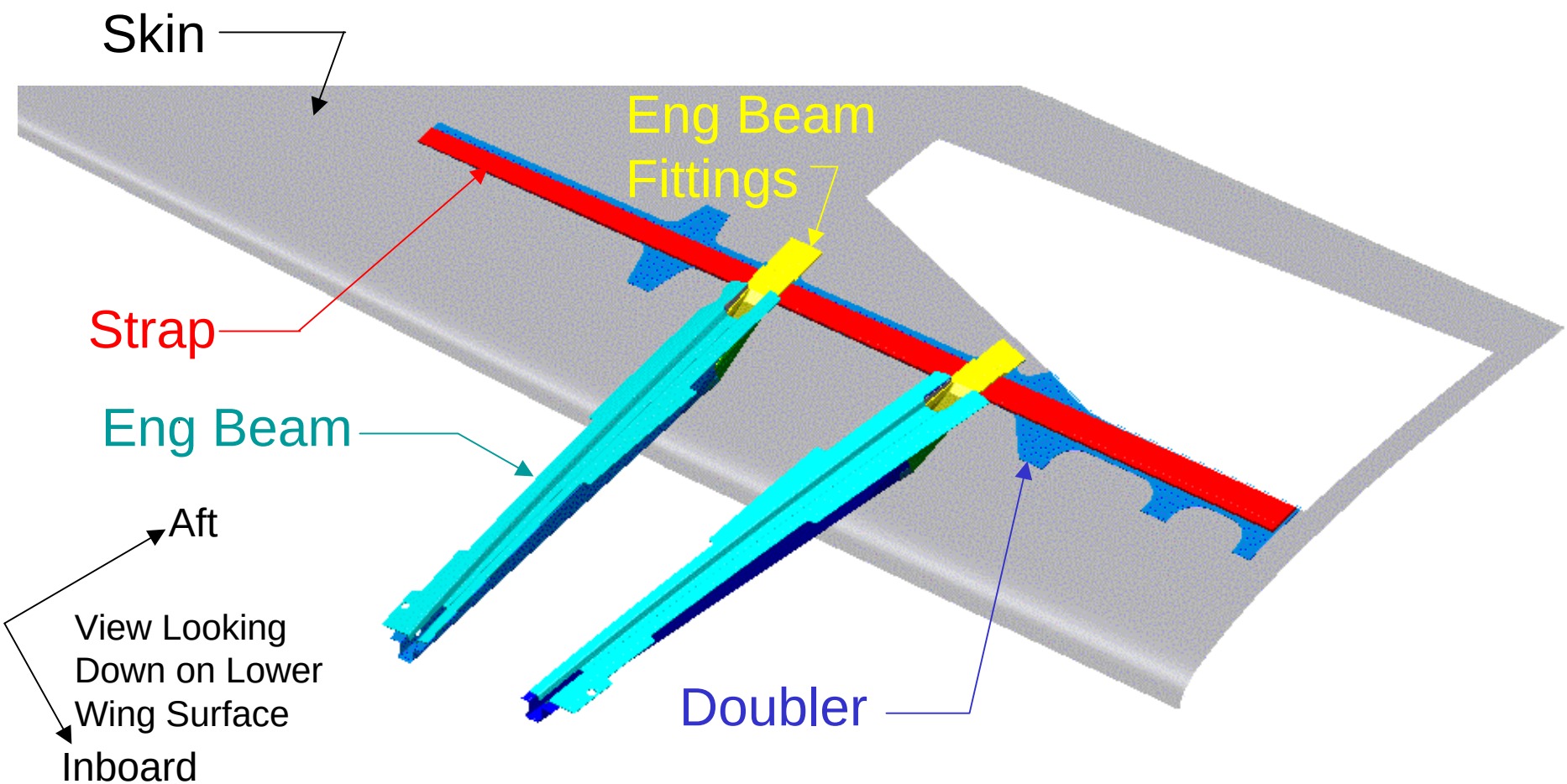
Cessna
A Textron Company

Model 401/402/411 Wing Strap



Cessna
A Textron Company

Model 402C/414A Wing Strap



Cessna
A Textron Company

Agenda

- **Airframe Design History**
- Fatigue – General Concepts
- Analysis
- Fatigue Tests
- Field History
- NDI Options
- Wing Modification Options
- Conclusion

Cessna
A Textron Company

Airframe Design History

Cessna 300 & 400 Series Airplanes

Cessna
A Textron Company

Cessna Model 402

Cessna
A Textron Company

Airframe Design History

- Cessna Model 402 (402/402A/402B)
  - Model 402 designed in 1967
    - Twin-engine unpressurized airplane
    - Seats up to 9 passengers
    - Dry wing with tip tanks
  - Model 402 wing structurally similar to Cessna Model 310 wing
    - Two spar design
    - The first Model 310 was designed in 1954
    - Certified to CAR 3 requirements
      - No specific fatigue or failsafe requirements
    - Spar caps made from 7075-T6 material
      - High strength aluminum, high crack growth rate
    - Gross weight for Model 402 significantly increased over Model 310 gross weight

Cessna
A Textron Company

Airframe Design History

Airplane Certified Gross Weight

Model	Gross Weight (lb)	
310	4600	(original)
	5500	(later models)
401	6300	
402	6300	
411	6500	
402C	6850	
414A	6750	

Cessna
A Textron Company

Cessna Model 402C

Cessna
A Textron Company

Airframe Design History

- Cessna Model 402C
  - Designed in 1979
  - Two spar design
  - Wet wing, no tip tanks
  - Spar caps increased in size over Model 402
    - Made from 7075-T76511 aluminum
    - Improved fatigue characteristics

Cessna
A Textron Company

Airframe Design History

- Cessna Model 414A (units 1-200)
  - Wing is structurally similar to Model 402C
  - Spar cap is same size as Model 402
- Cessna Model 414A (units 201 and on)
  - Wing is structurally similar to Model 402C
  - Spar cap is same size as Model 402C
- Cessna Models 401 and 411
  - Wing is structurally similar to Model 402
  - Spar cap is same size as Model 402

Cessna
A Textron Company

Agenda

- Airframe Design History
- **Fatigue – General Concepts**
- Analysis
- Fatigue Tests
- Field History
- NDI Options
- Wing Modification Options
- Conclusion

Cessna
A Textron Company

Fatigue

General Concepts

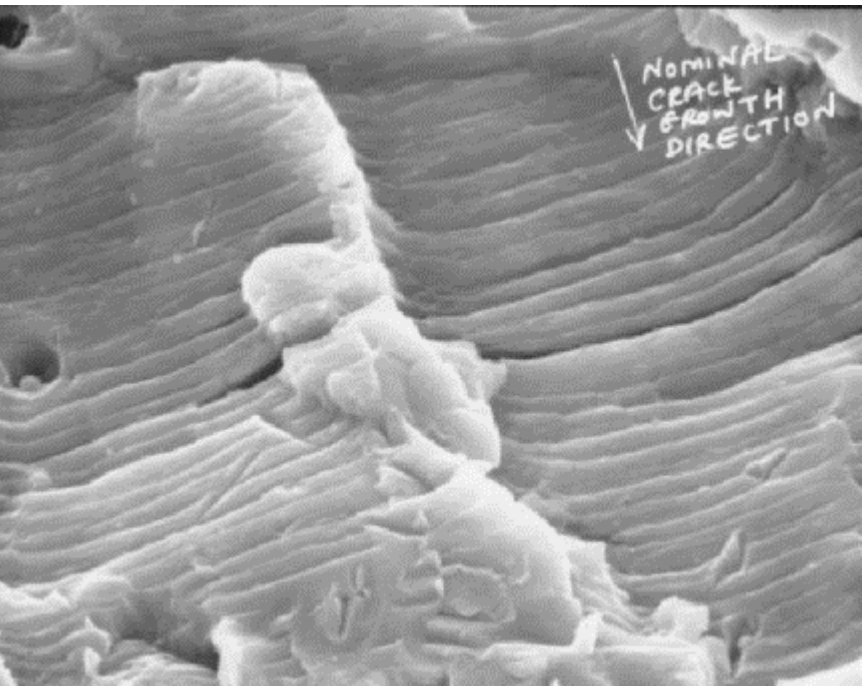
Cessna
A Textron Company

Fatigue

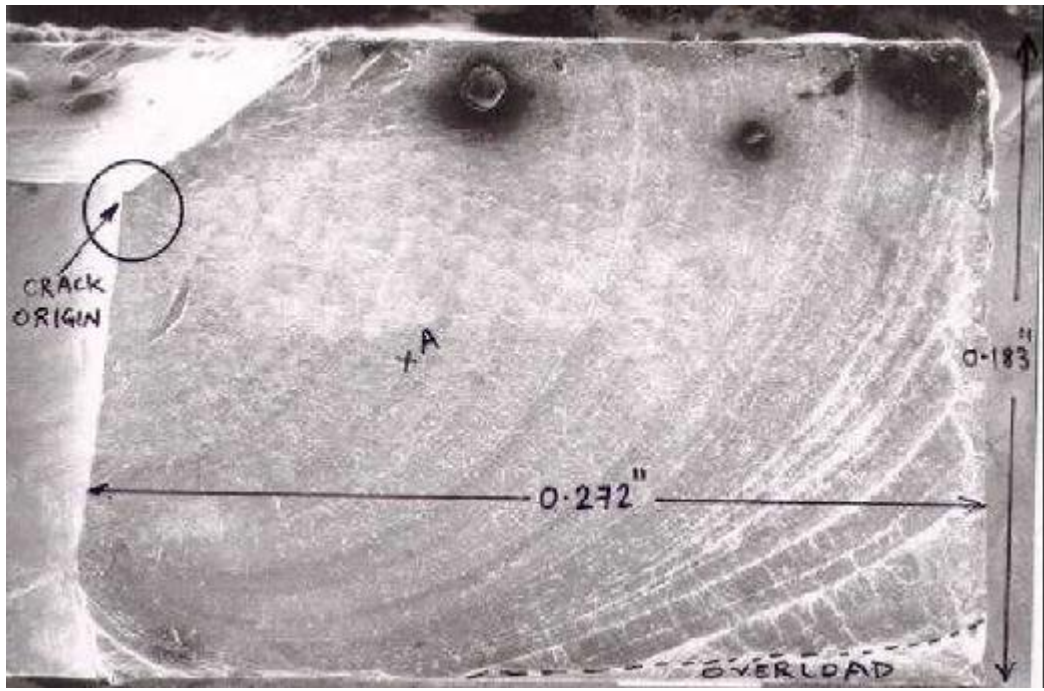
- What is fatigue?
  - In the airplane, the metal atoms cluster together in crystals
  - Every time the airplane takes off, hits a gust, pulls a maneuver or lands, the loads push and pull on the metal atoms so that microscopic cracks develop in the crystal
  - With each load, these cracks jump from one crystal to the next
  - Thus, flight by flight the crack grows
  - This process is called fatigue because the metal gets tired after being loaded and unloaded over and over again

Cessna
A Textron Company

Fatigue Fracture Face



Fatigue Striations



Beach Marks

Cessna
A Textron Company

Fatigue

- Fatigue can be deadly
  - According to a Canadian survey, metal fatigue contributed to 2240 deaths in 1885 airplane accidents between 1927 and 1980[1]
  - Over 700 people have died in fatigue related accidents since 1980[2]

1 Campbell and Lahey 1984, 'A Survey of Serious Aircraft Accidents Involving Fatigue Fracture', *International Journal of Fatigue,* January 1984

2 'Investigation into Ansett Australia Maintenance Safety Deficiencies and the Control of Continuing Airworthiness of Class A Aircraft', Appendix 8 from the Australian Transport Safety Bureau's web site, www.atsb.gov.au.

Cessna
A Textron Company

Aloha Airlines - 1988

Cessna
A Textron Company

Lockheed C130A - 2002

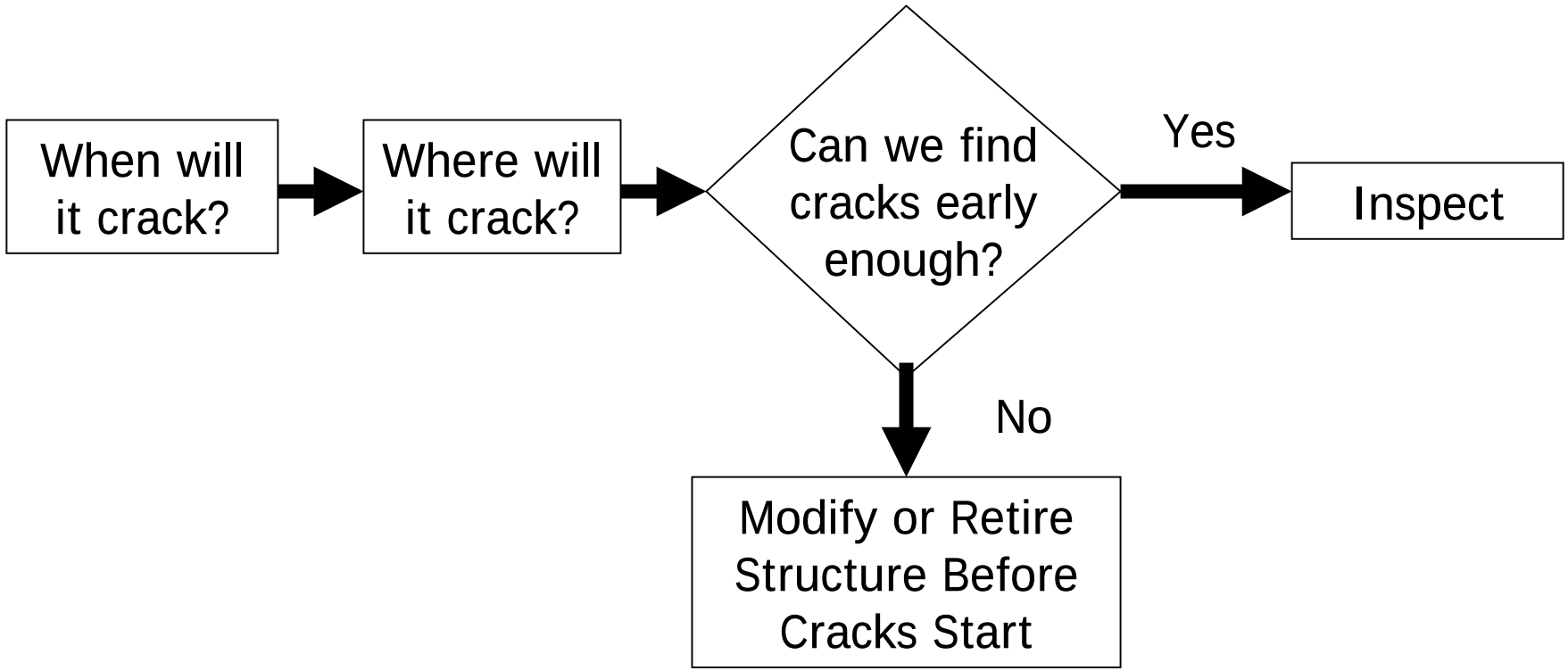
Cessna
A Textron Company

Fatigue

- Fatigue is inevitable
- If a crack is not found and fixed, the crack will continue to grow
- The longer the crack grows, the faster it grows until there is not enough structure left to carry the load and the part breaks
- We can’t stop the fatigue process
- We can control its dangerous effects

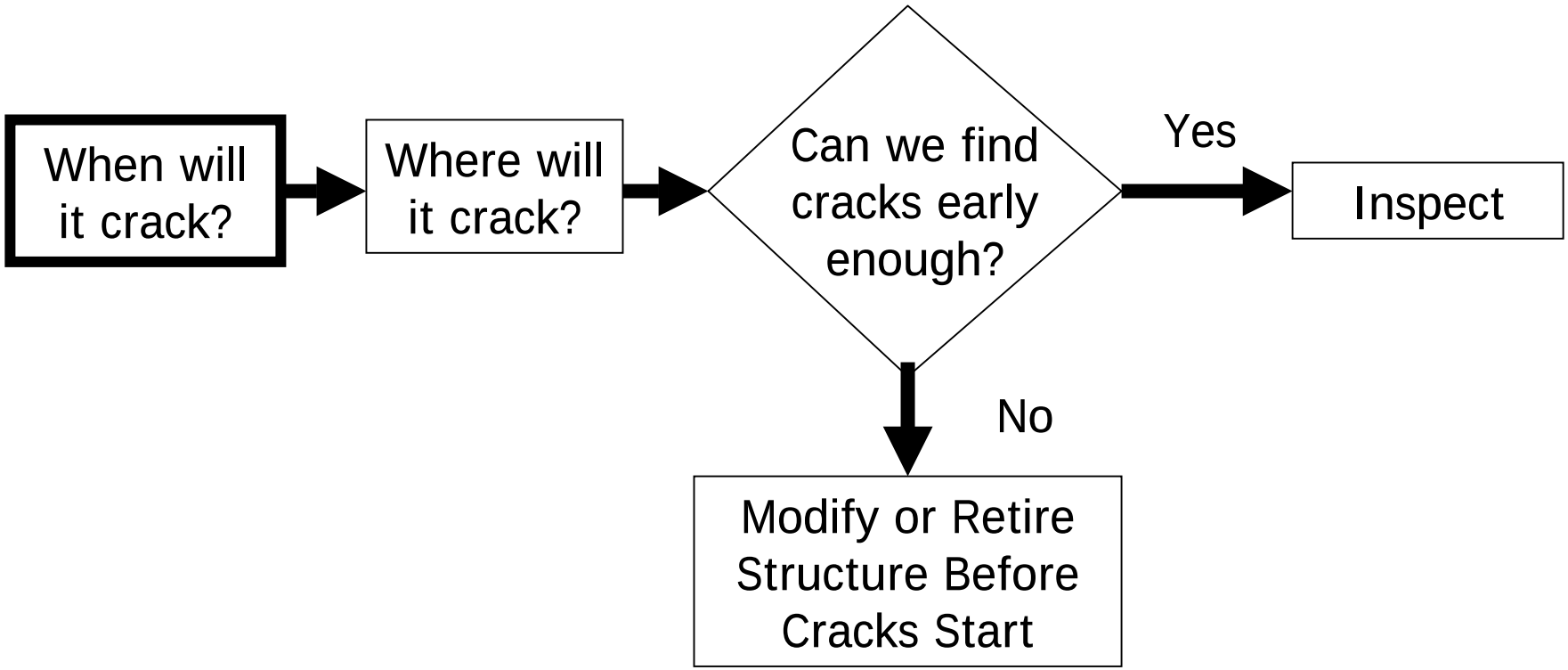
Cessna
A Textron Company

Options For Controlling Fatigue



Cessna
A Textron Company

Options For Controlling Fatigue



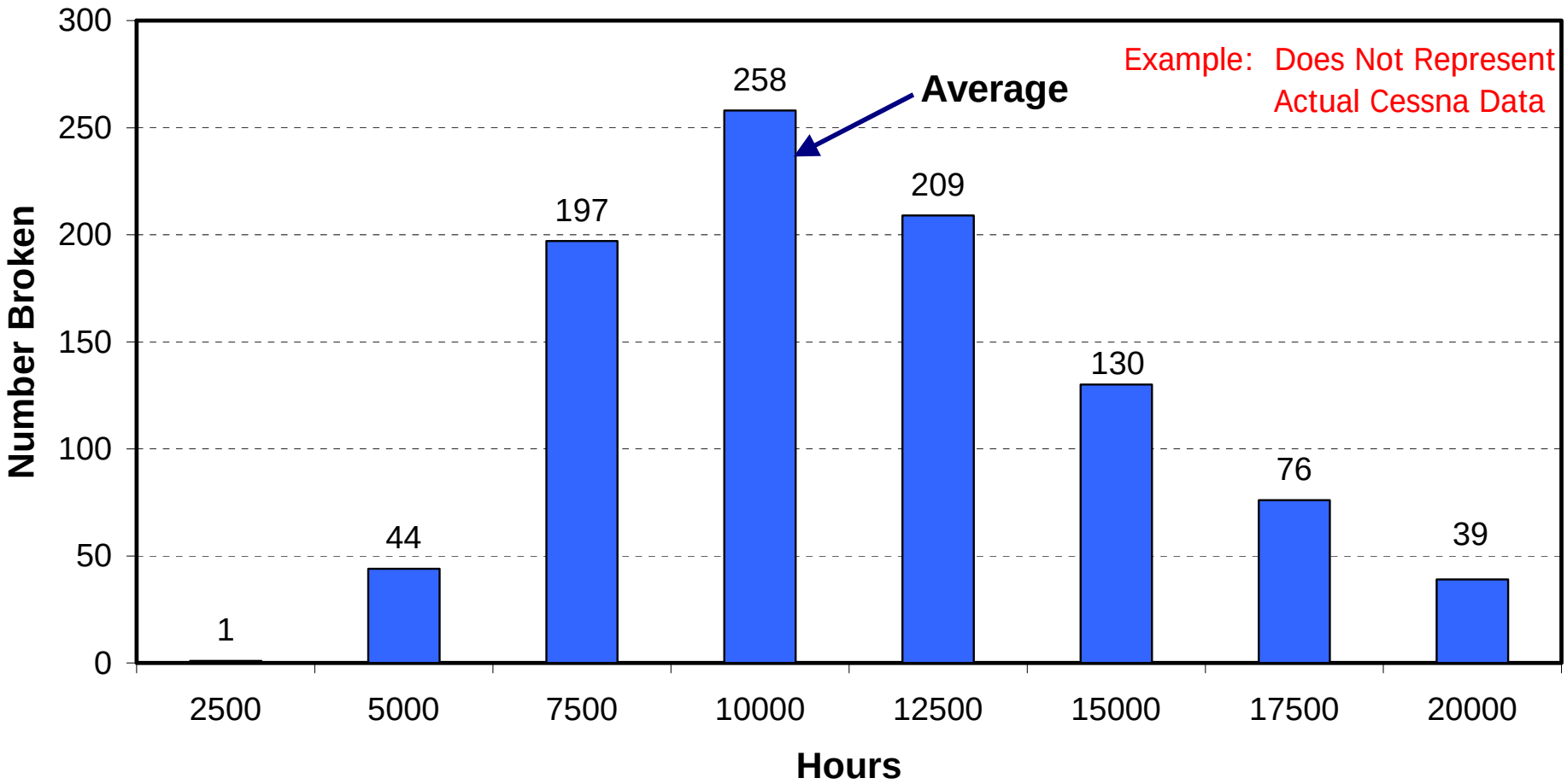
Cessna
A Textron Company

When Will It Crack?

- Suppose 1000 identical wing spars were fatigue tested with the same loads
- Assume the average wing spar breaks at 10,000 hours
- They won't all break at the same time

Cessna
A Textron Company

1000 Wing Spars Fatigue Tested



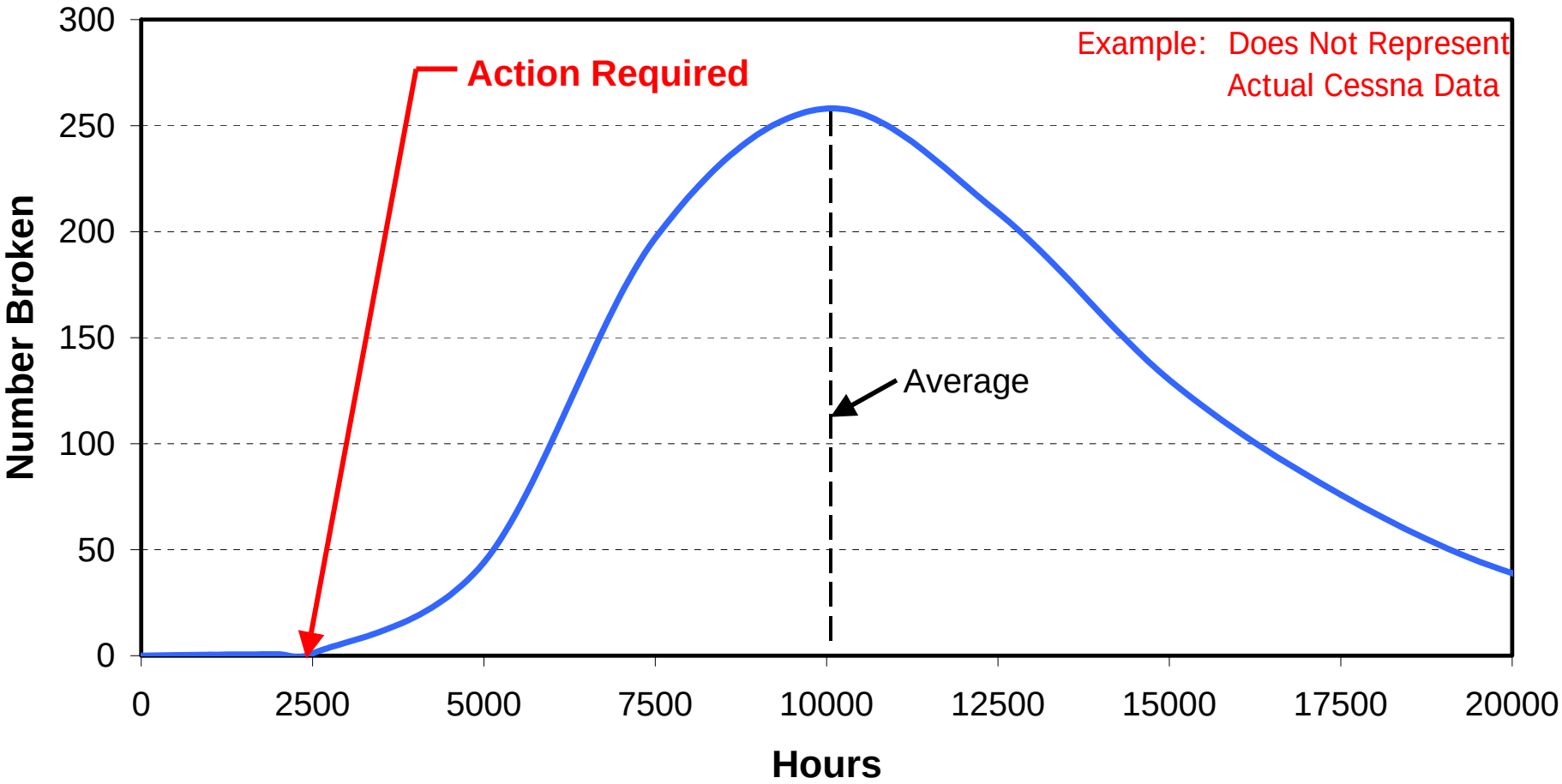
Cessna
A Textron Company

When Will It Crack?

- First wing spar will break at 2,500 hours
- Last wing spar won't break until after 120,000 hours
- The problem is that we don't know beforehand which one will break first
- When is action required?
- What level of risk do we accept?

Cessna
A Textron Company

When Is Action Required?



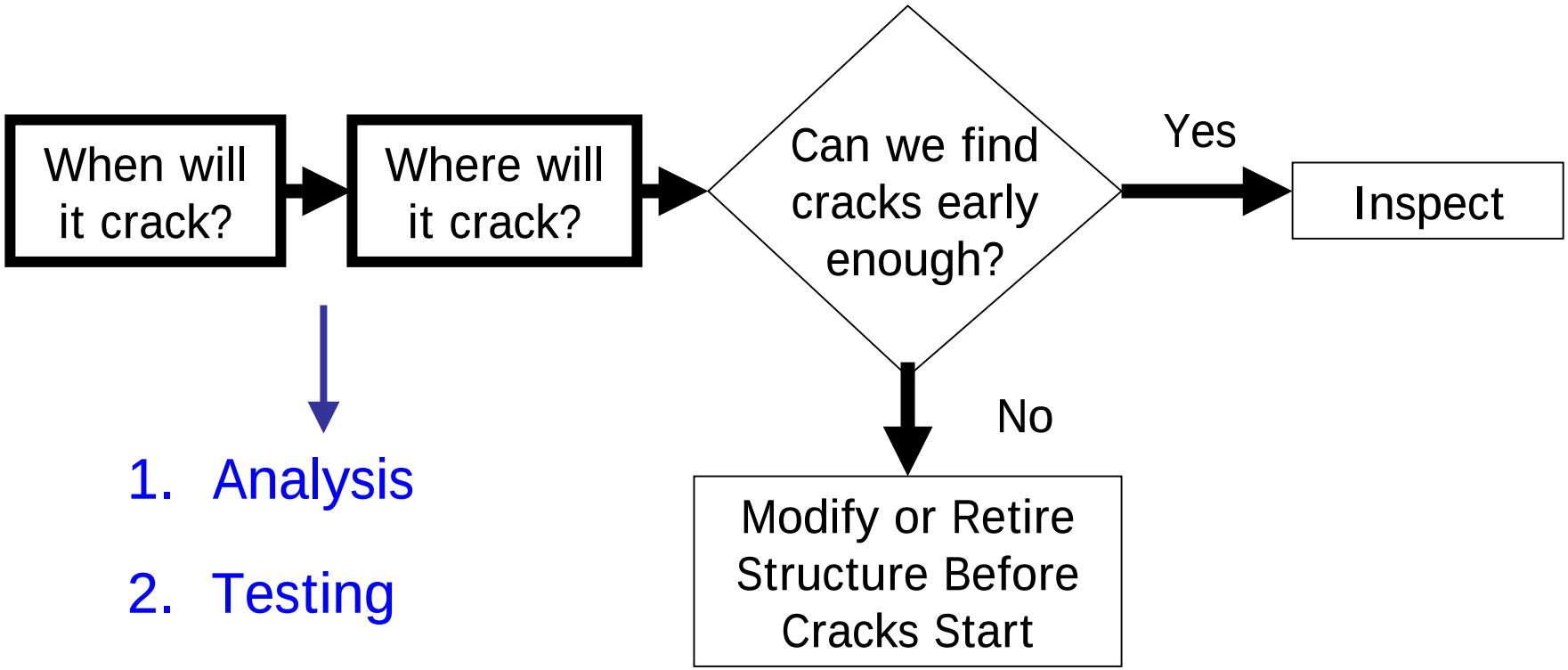
Cessna
A Textron Company

When Will It Crack?

- Other factors which may also lower the expected life of the spar
  - Corrosion
  - Accidental Damage
  - Repairs
  - Manufacturing Variation
  - Environment

Cessna
A Textron Company

Options For Controlling Fatigue



1. Analysis
2. Testing
3. Field Experience

Cessna
A Textron Company

Agenda

- Airframe Design History
- Fatigue – General Concepts
- **Analysis**
- Fatigue Tests
- Field History
- NDI Options
- Wing Modification Options
- Conclusion

Cessna
A Textron Company

Analysis

Fatigue & Crack Growth

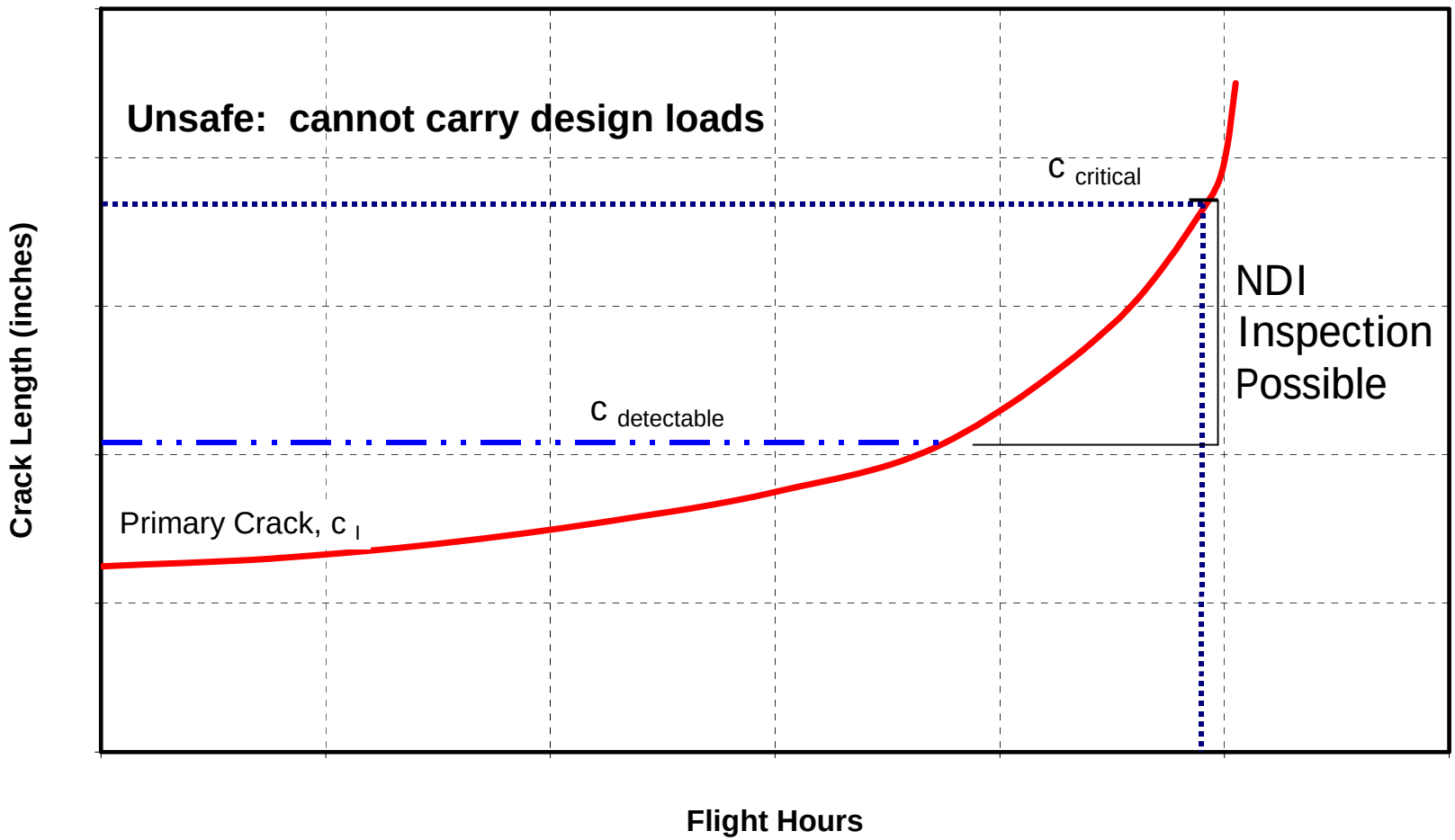
Cessna
A Textron Company

Analysis

- Fatigue analysis
  - Determine when the part is first expected to crack
- Crack growth analysis
  - Determine how fast a crack will grow
- Residual strength analysis
  - Determine how much load a part will carry with a certain size crack

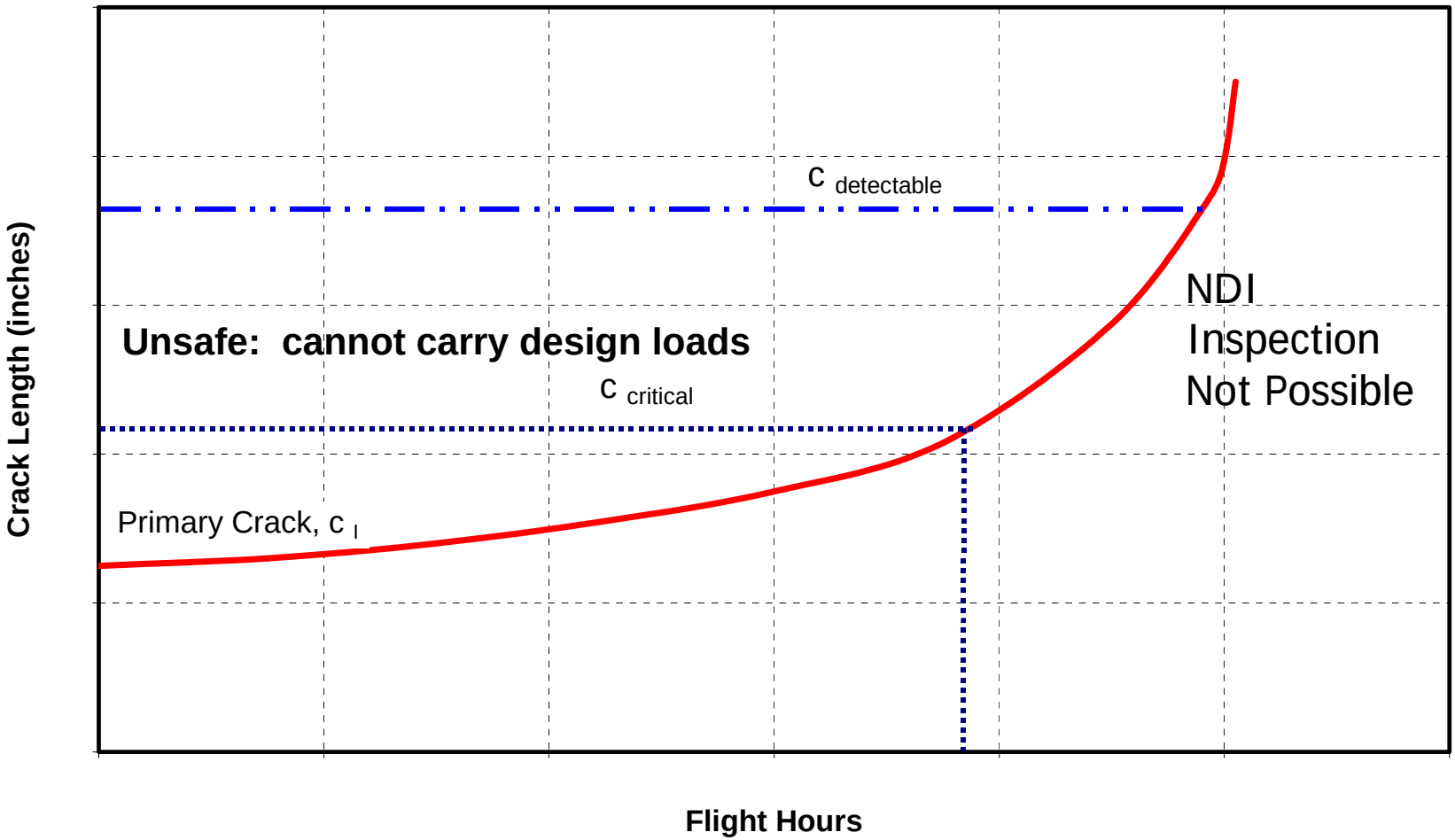
Cessna
A Textron Company

Crack Growth Analysis



Cessna
A Textron Company

Crack Growth Analysis

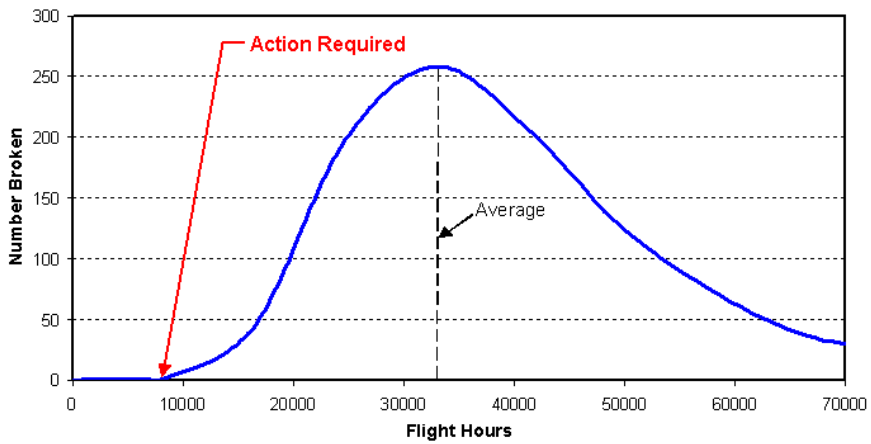


Analysis

- Models 401, 402, 411
  - Fatigue analyses first conducted shortly after certification (1970s)
    - 8,200 hours for Models 401 and 402
    - 6,800 hours for Model 411

FAA Public Meeting –Proposed Cessna Wing Spar AD
3-4 March 2004 – Washington D.C.

When Is Action Required?



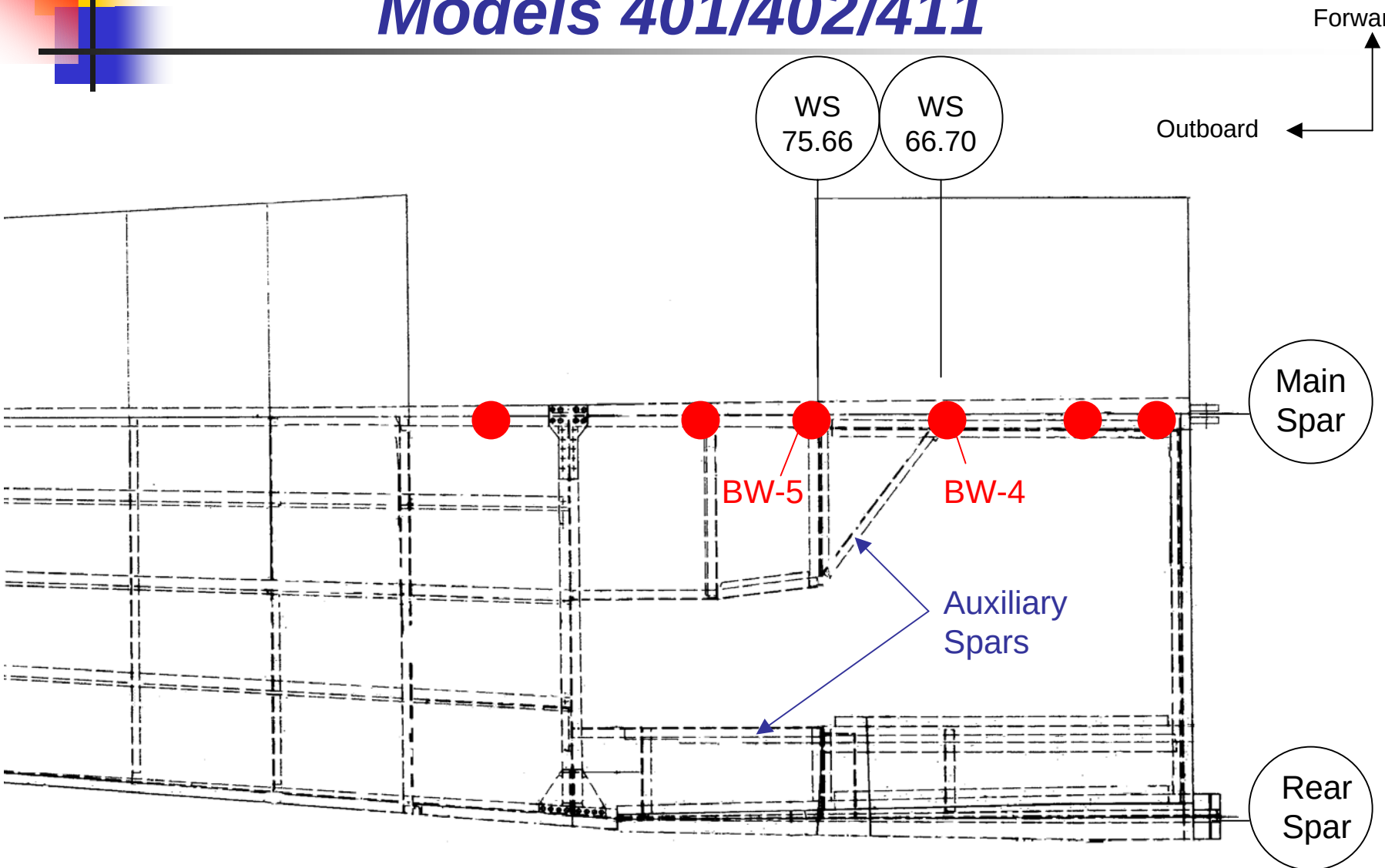
Cessna
A Textron Company

Analysis

- Models 401, 402, 411
  - Basis of life limits in Australia and United Kingdom
  - Lowest fatigue life is BW-5, WS 75.66
  - Second lowest fatigue life is BW-4, WS 66.70

Main Spar Analysis Locations Models 401/402/411

Cessna
A Textron Company



Cessna
A Textron Company

Analysis

- Models 401, 402, 411
  - In 1997, new analyses were accomplished as part of the FAA SID (Supplemental Inspection Document) contract for the Models 401/402
  - New analyses were later completed for Model 411
  - Fatigue analysis
    - 5,400 hours for Model 411
    - 5,800 hours for Model 402

Cessna
A Textron Company

Analysis

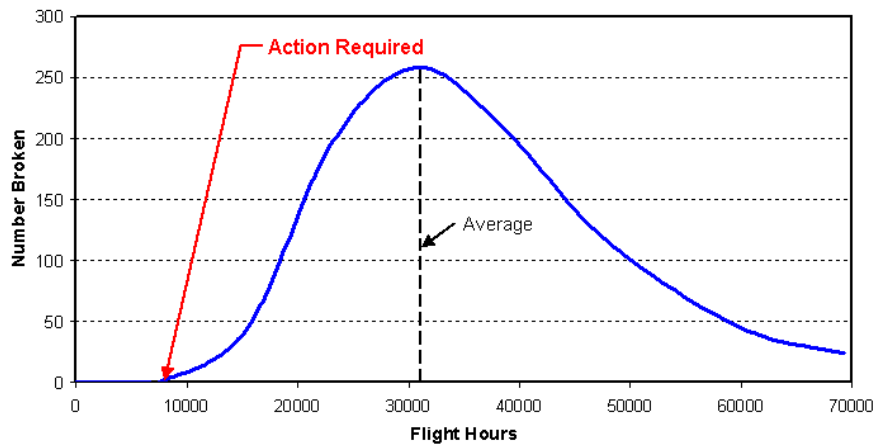
- What load will the Model 402 wing carry if the main spar cap breaks?
  - The wing will carry less than 70% of limit load
    - Limit load is the largest load the wing is expected to see in a lifetime
    - CAR 3.173 of the original certification basis does not provide for relaxation of the strength requirements based on age
    - Therefore the wing cannot carry the required load
  - Applicable to wings with the smaller spar caps, Models 401, 402, 411 and 414A, units 1-200

Analysis

- Models 402C and 414A
  - Fatigue analyses first conducted about the time of certification (late 1970s)
    - 6,400 hours for Model 414A, units 1-200, and 13,700 hours for Model 414A, units 201 & on
    - 7,700 hours for Model 402C

FAA Public Meeting –Proposed Cessna Wing Spar AD
3-4 March 2004 – Washington D.C.

When Is Action Required?

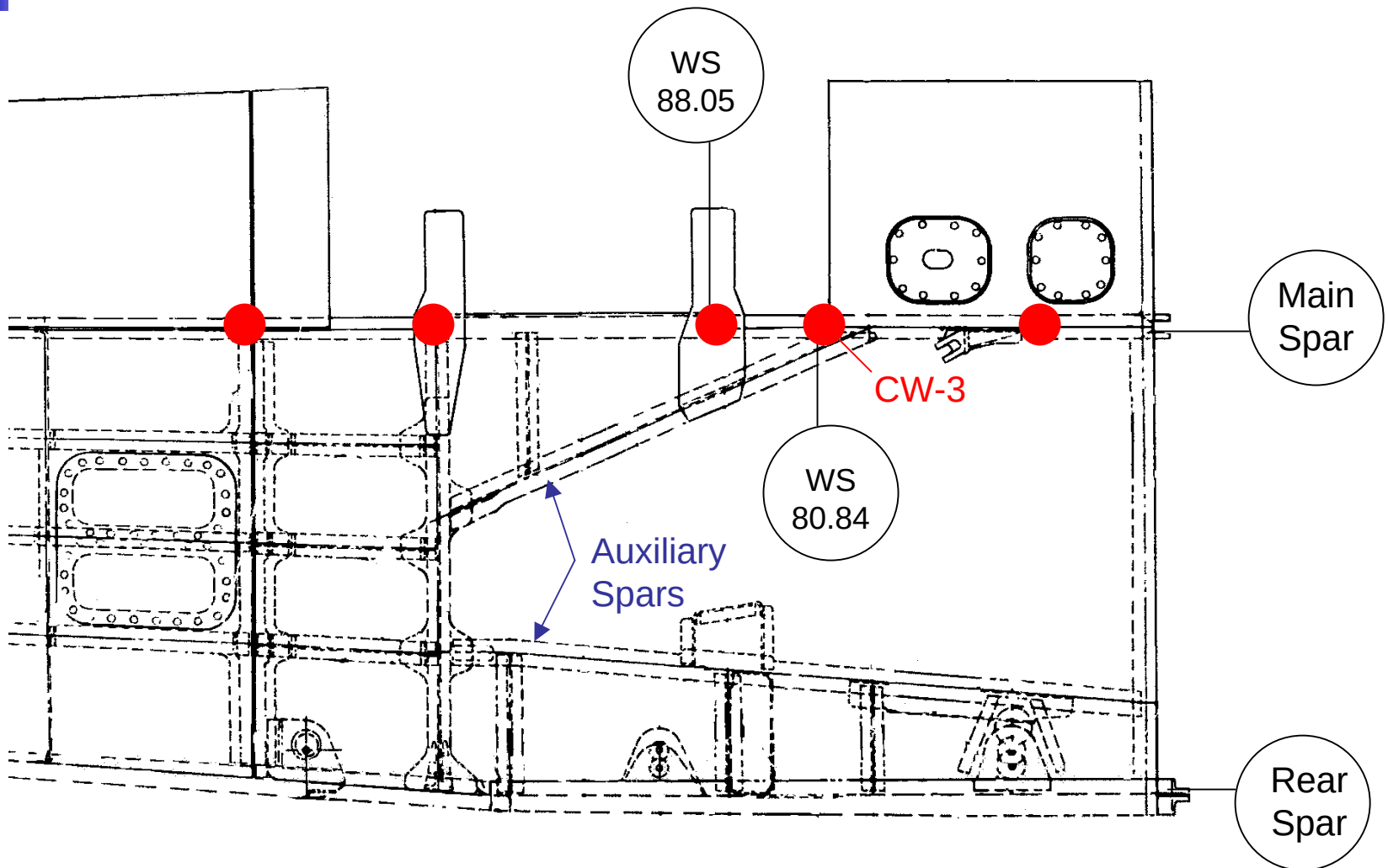


Cessna
A Textron Company

Analysis

- Models 402C and 414A
  - Basis of life limits in Australia and U.K.
  - Lowest fatigue life is CW-3, WS 80.52

Analysis Locations Models 402C/414A



Cessna
A Textron Company

Analysis

- Models 402C, 414A
  - In 1997, new analyses were accomplished as part of the SID contract for the Model 402C
  - New analyses accomplished later for Model 414A
  - Fatigue analysis
    - 9,100 hours for Model 414A, units 1-200
    - 15,000 hours for Model 414A, units 201 & on
    - 15,000 hours for Model 402C

Cessna
A Textron Company

Analysis

- What load will the Model 402C wing carry if the spar cap breaks?
  - The wing will carry 100% of limit load for a period of time after the spar breaks (based on analysis and full-scale test results)
    - Applicable to wings with the larger spar caps, Models 402C and 414A, units 201 & on

Cessna
A Textron Company

Agenda

- Airframe Design History
- Fatigue – General Concepts
- Analysis
- **Fatigue Tests**
- Field History
- NDI Options
- Wing Modification Options
- Conclusion

Cessna
A Textron Company

Fatigue Tests

- The accuracy of the analysis is verified by fatigue test results
- Two fatigue tests were conducted on the Model 402 wing
  - First test conducted in 1974.
    - Main spar lower cap broke after 14,000 simulated flight hours
    - Three other cracks developed in spar cap during 63,000 simulated flight hours

Cessna
A Textron Company

Fatigue Tests

- Second test conducted in 1975.
  - Wing with a “short” reinforcement strap tested for 40,000 simulated flight hours
  - After testing was completed, the spar cap was cut and wing tested to limit load (strap intact) without failure
  - During teardown examination, small cracks were found in spar cap in areas not reinforced by the reinforcement strap

Cessna
A Textron Company

Agenda

- Airframe Design History
- Fatigue – General Concepts
- Analysis
- Fatigue Tests
- **Field History**
- NDI Options
- Wing Modification Options
- Conclusion

Cessna
A Textron Company

Field History

- The accuracy of the analysis is further supported by field history
  - Spar cap cracks have been discovered on six Model 402 airplanes
    - Five cracks were between WS 66 and WS 75 (analysis locations BW-4 and BW-5)
    - Sixth crack was at WS 81
    - Four instances were complete spar failure
    - Cracks were found between 8000 and 16,000 hours
    - All these airplanes were utilized in commuter service at the time the crack was found

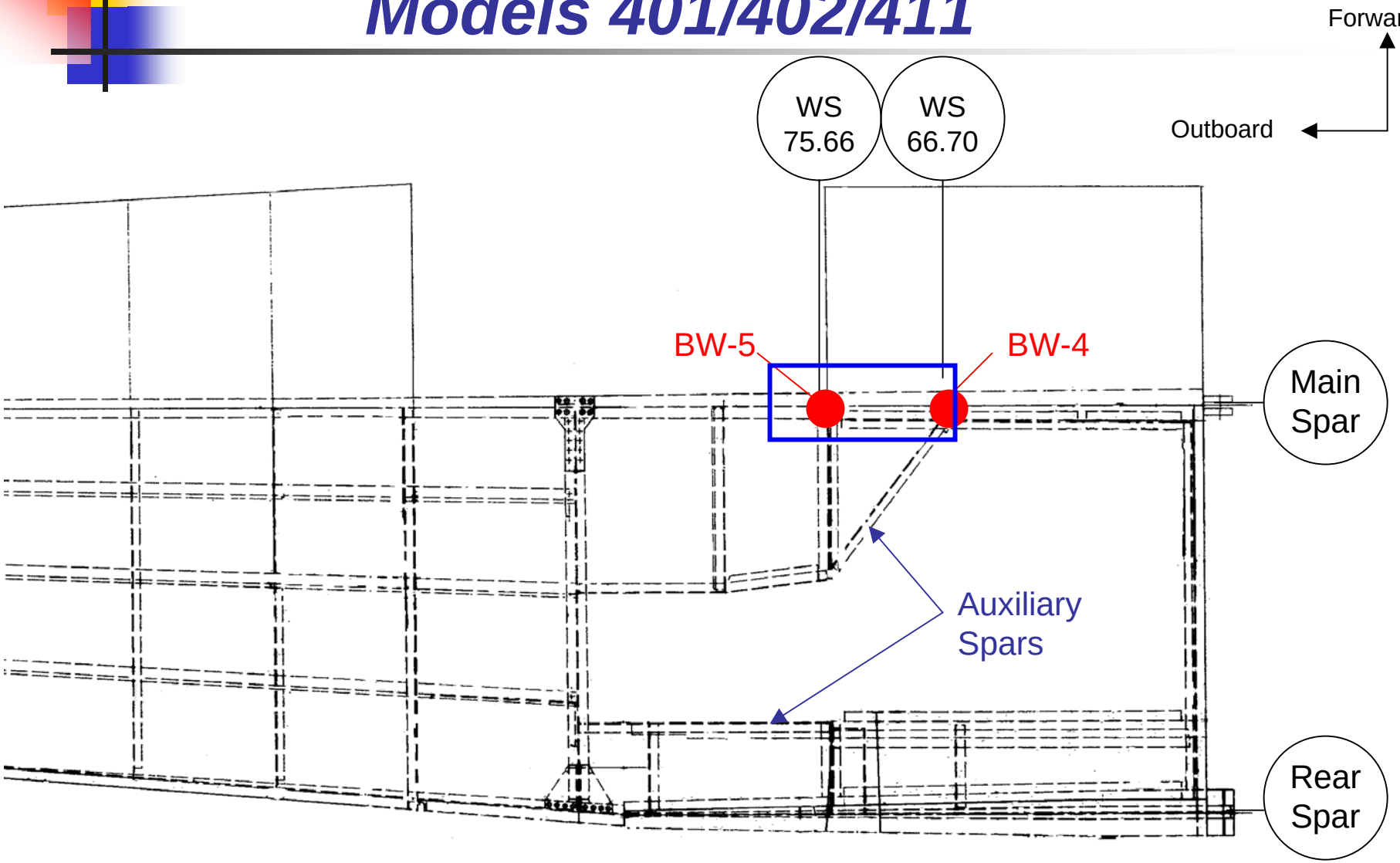
Cessna
A Textron Company

Field History

- One spar cap failure on Model 402C
  - Crack found after 20,400 hours
  - Crack located at WS 86.00, five inches from analysis location CW-3
  - This airplane was used to carry cargo at the time the crack was discovered

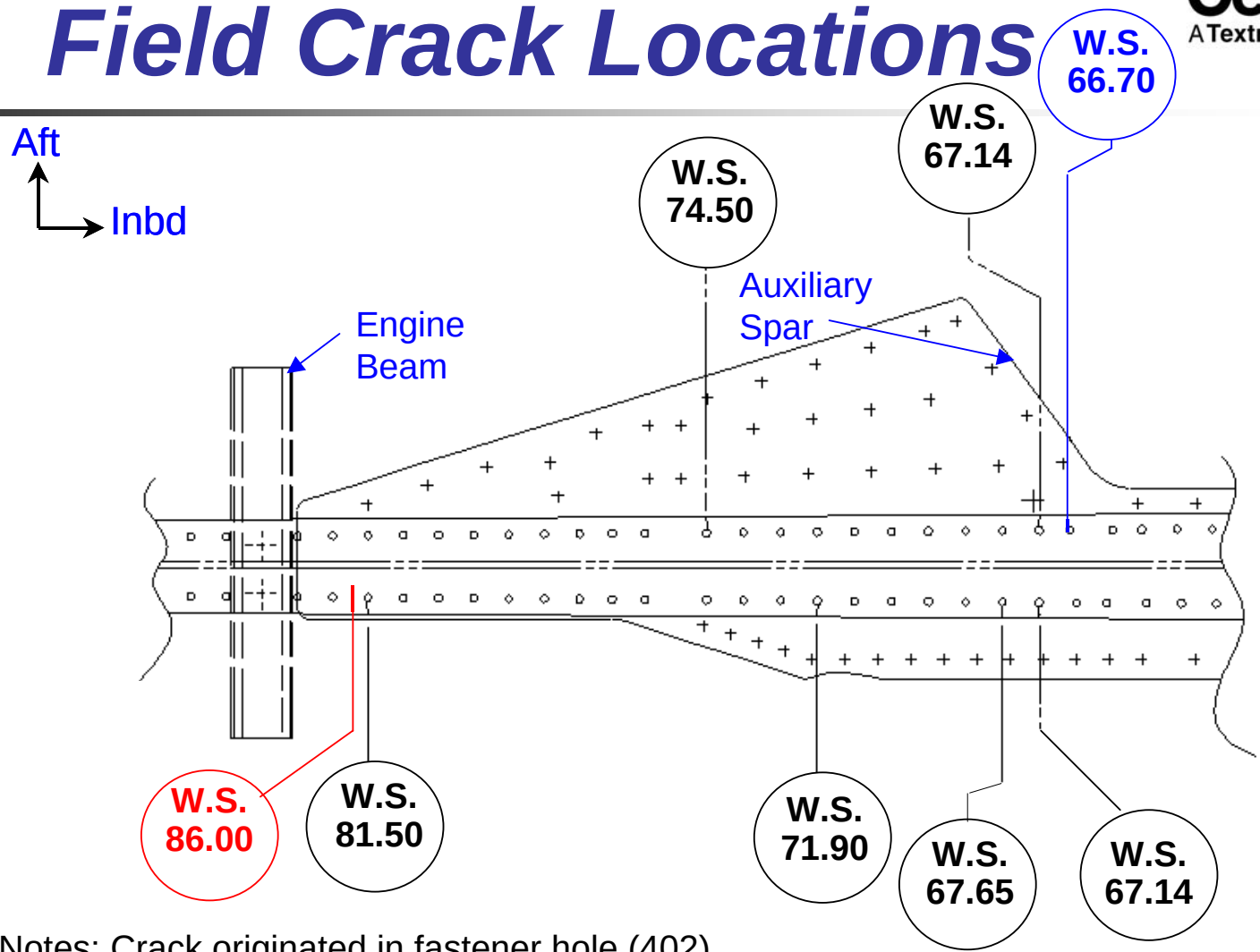
Analysis Locations Models 401/402/411

Cessna
A Textron Company



Cessna
A Textron Company

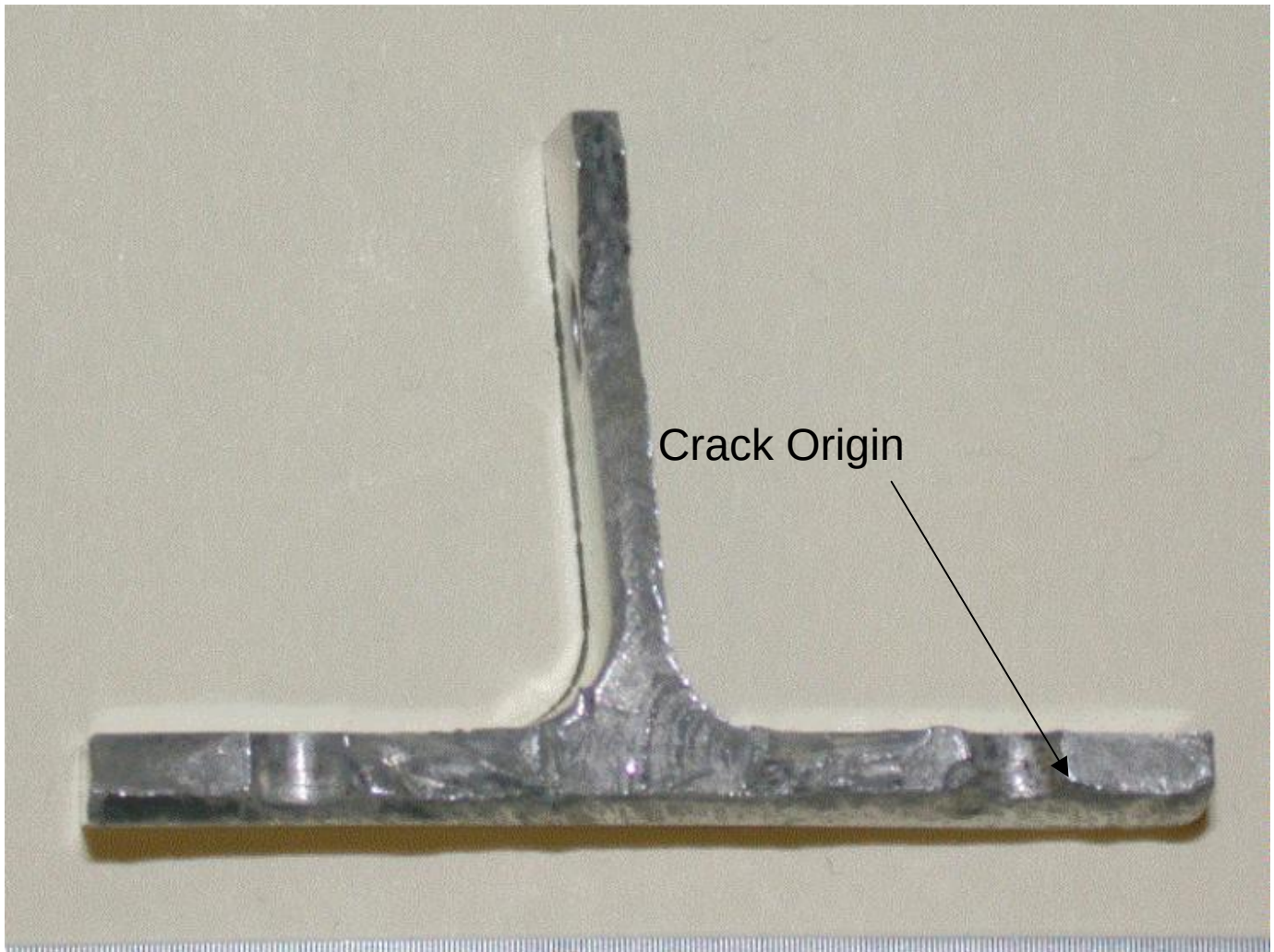
Field Crack Locations



Notes: Crack originated in fastener hole (402)
Crack originated at spar cap edge (402C)
Fatigue test crack origin (reference)

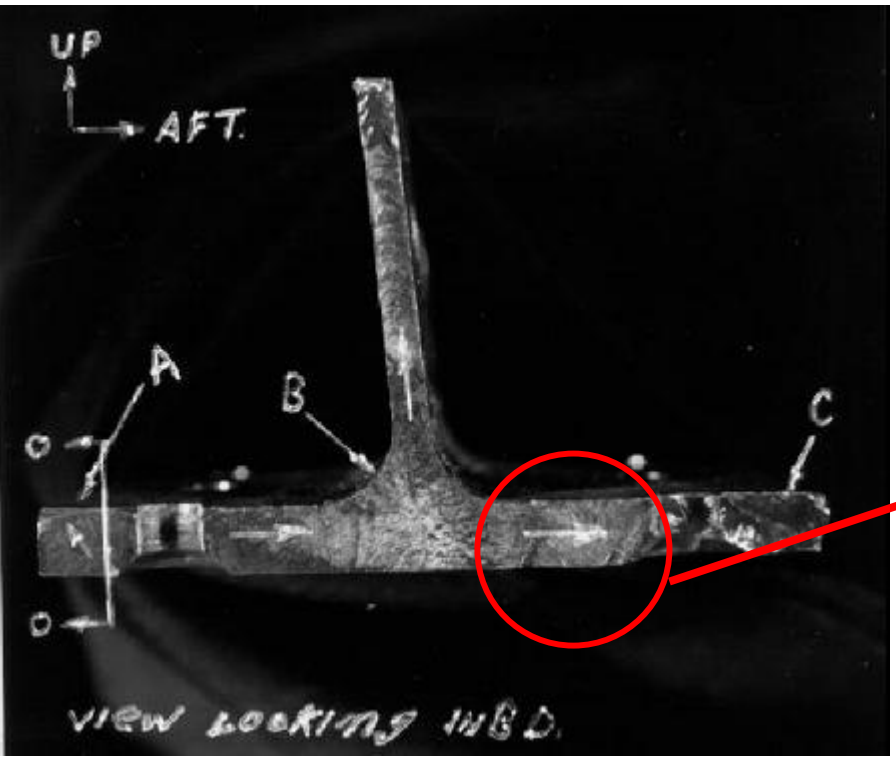
Cessna
A Textron Company

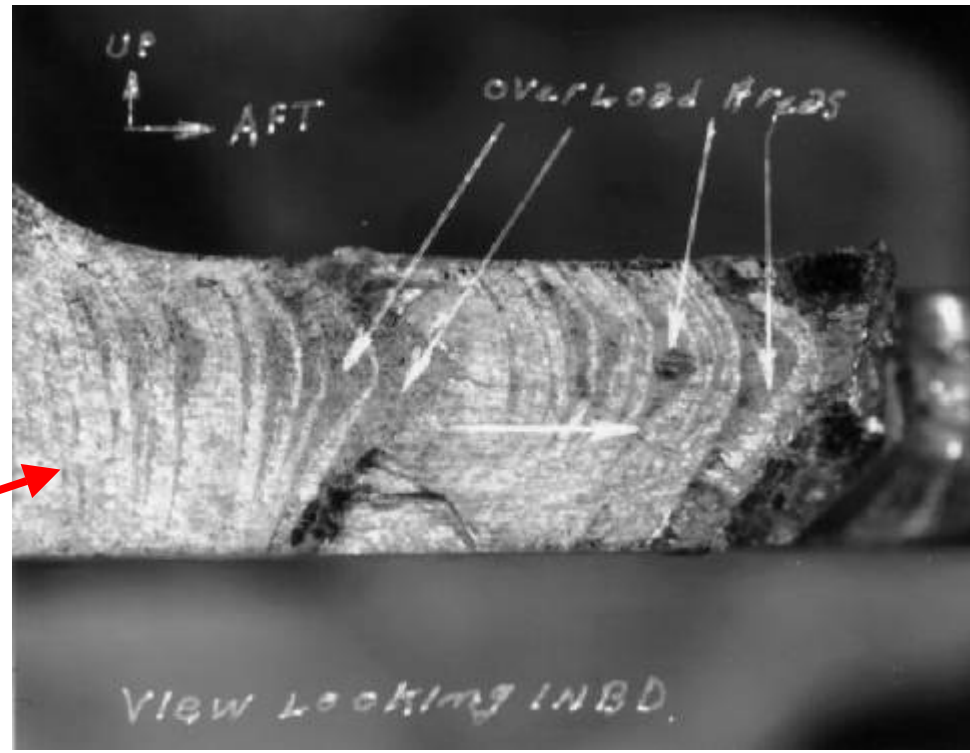
402-0295 Fracture Face



Cessna
A Textron Company

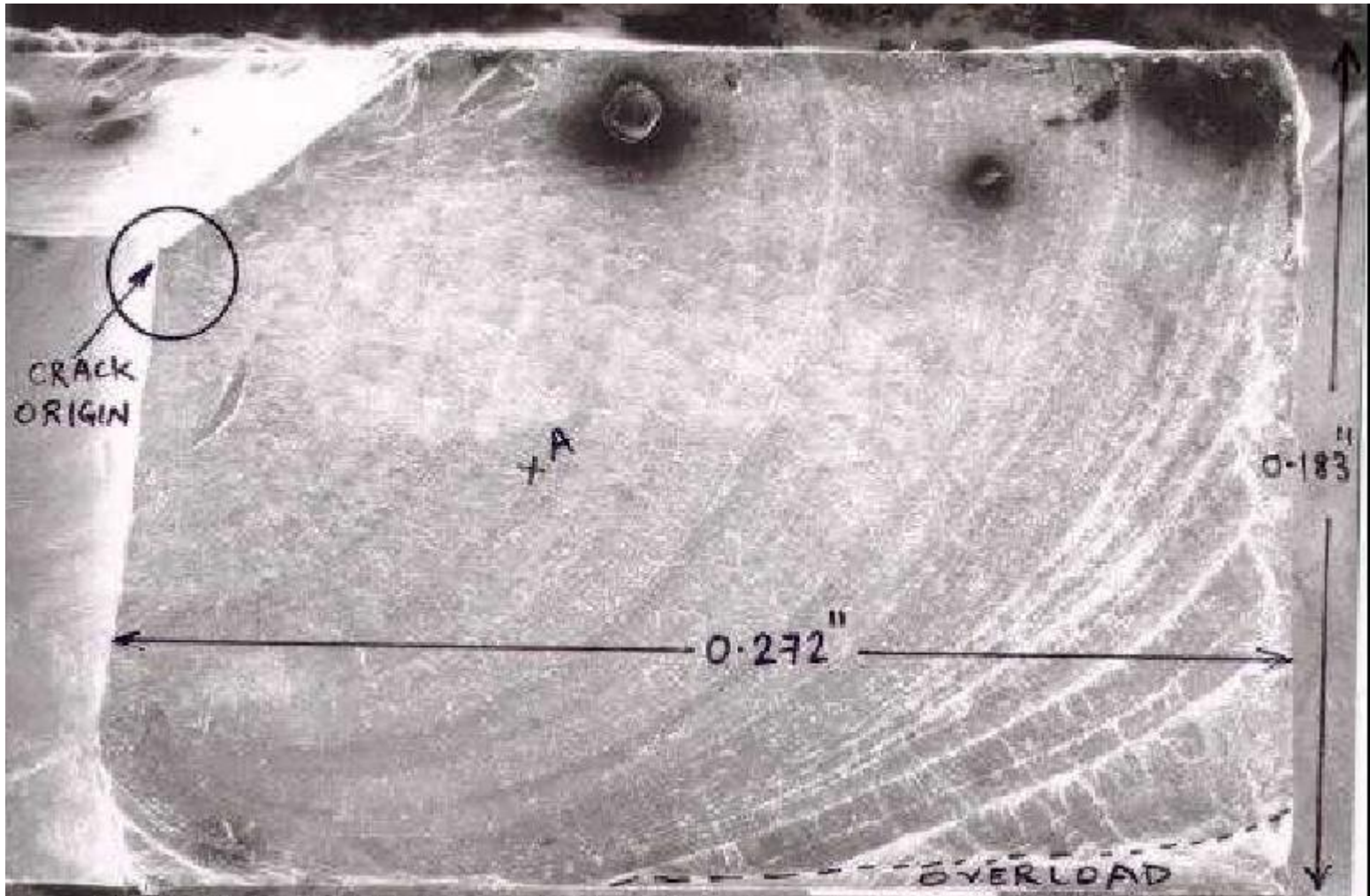
402-0101 Fracture Face





Cessna
A Textron Company

402A-0080 Fracture Face

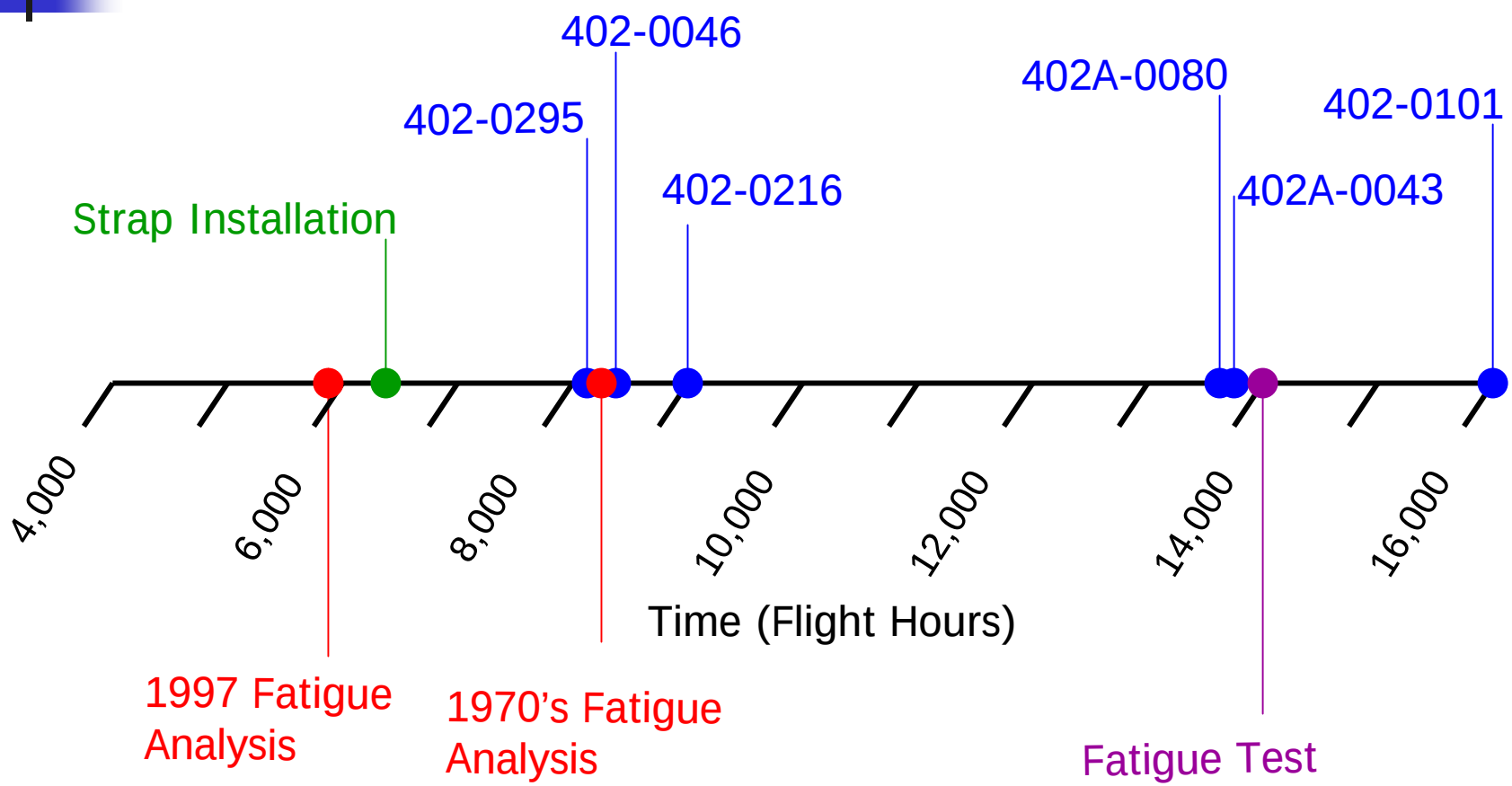


Down

Aft

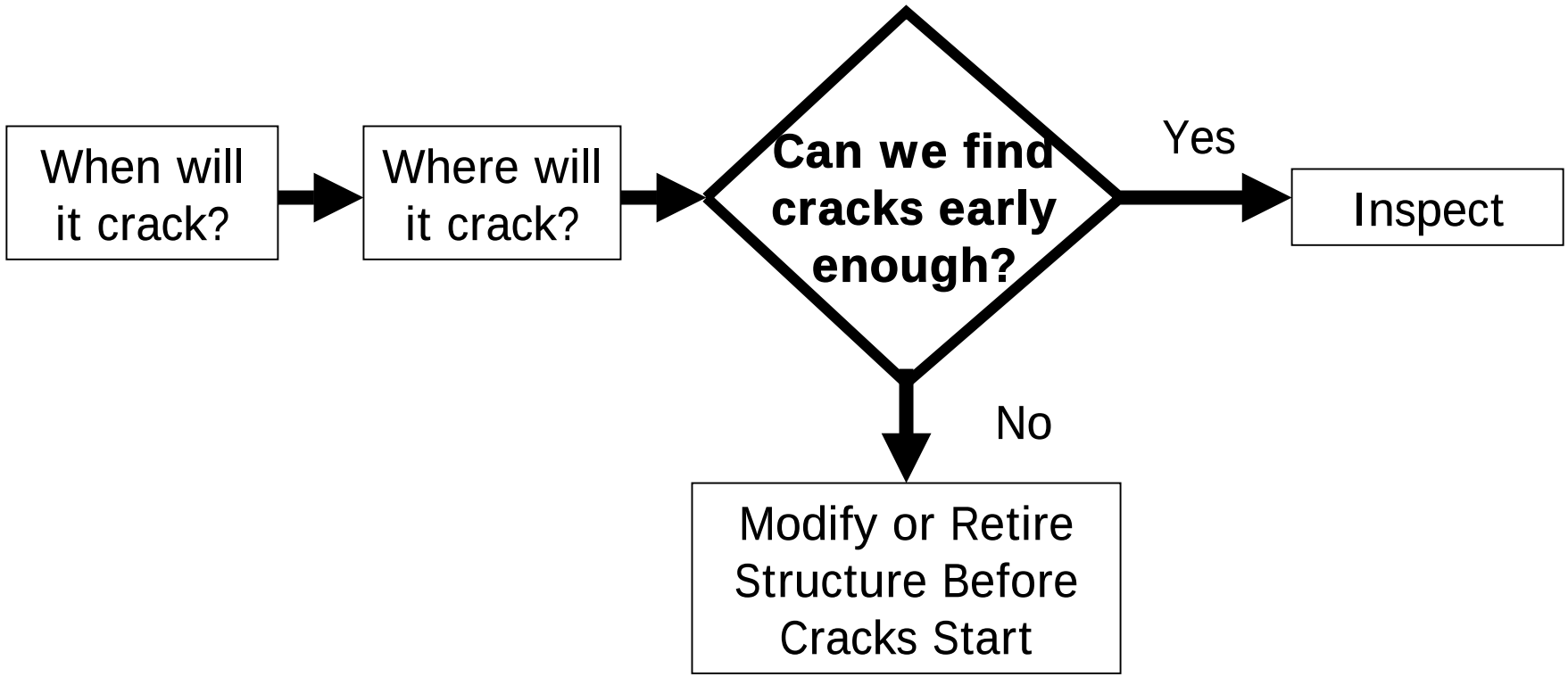
Cessna
A Textron Company

Analysis/Test/Field Comparison



Cessna
A Textron Company

Options For Controlling Fatigue



Cessna
A Textron Company

Agenda

- Airframe Design History
- Fatigue – General Concepts
- Analysis
- Fatigue Tests
- Field History
- **NDI Options**
- Wing Modification Options
- Conclusion

Cessna
A Textron Company

Existing NDI Procedure

- In 1979, Cessna issued Service Bulletin ME79-16 for the Models 401, 402 and 411
  - Surface eddy current inspect spar every 400 hours
  - AD 79-10-15 issued
  - At that time, this seemed to be the best way to protect the fleet
  - Now this inspection is viewed as inadequate to protect fleet

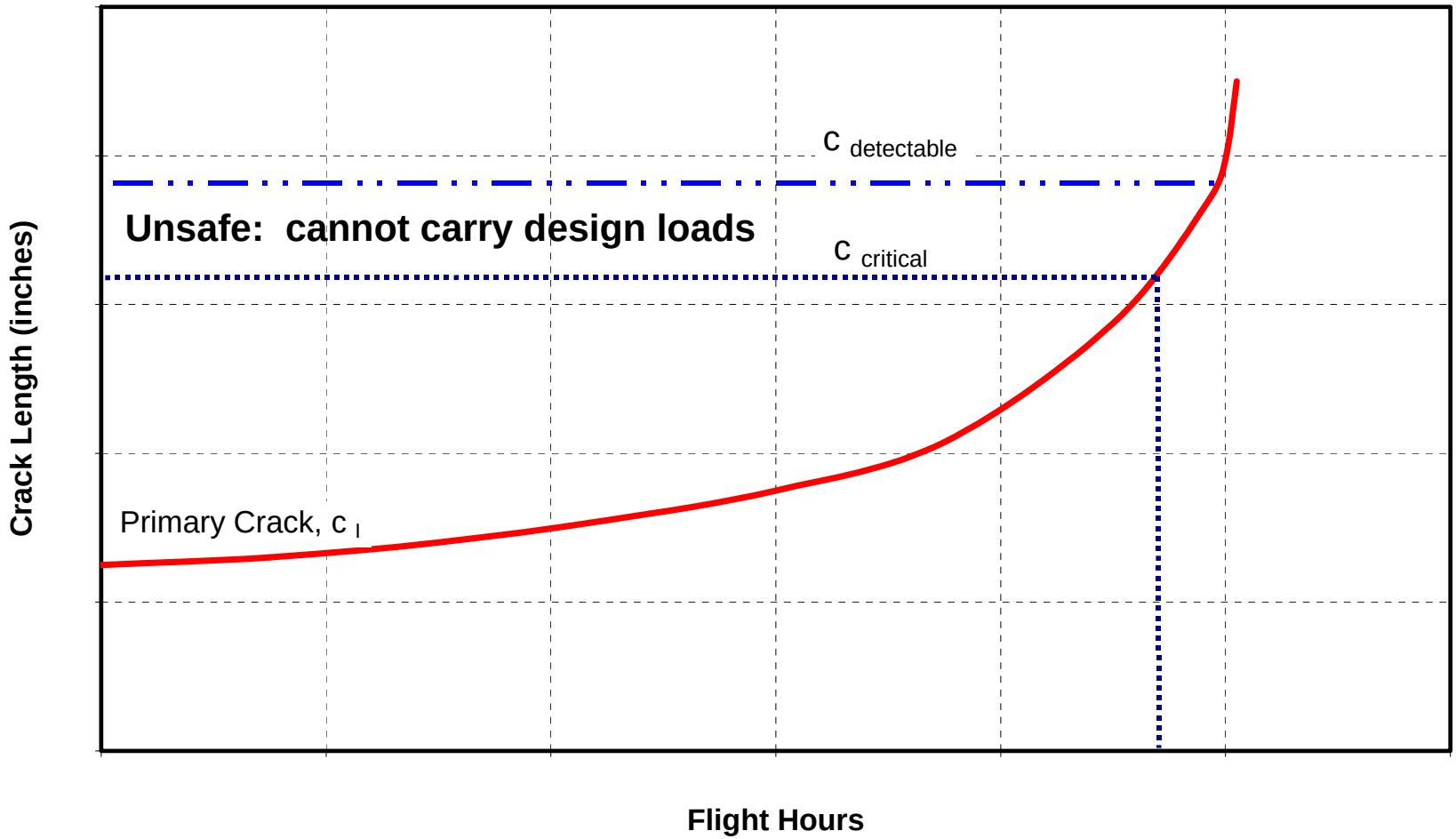
Cessna
A Textron Company

Existing NDI Procedure

- The industry standard is to find a crack with 90% probability of detection with 95% confidence
  - Surface eddy current method (per ME79-16 and AD 79-10-15) won't find crack until it is .19" which is .03" longer than the crack length which will no longer allow the spar to carry limit load
  - Once the spar is broken, the wing will no longer carry the required loads
  - Wing failure can occur in a very short period of time after spar cap breaks

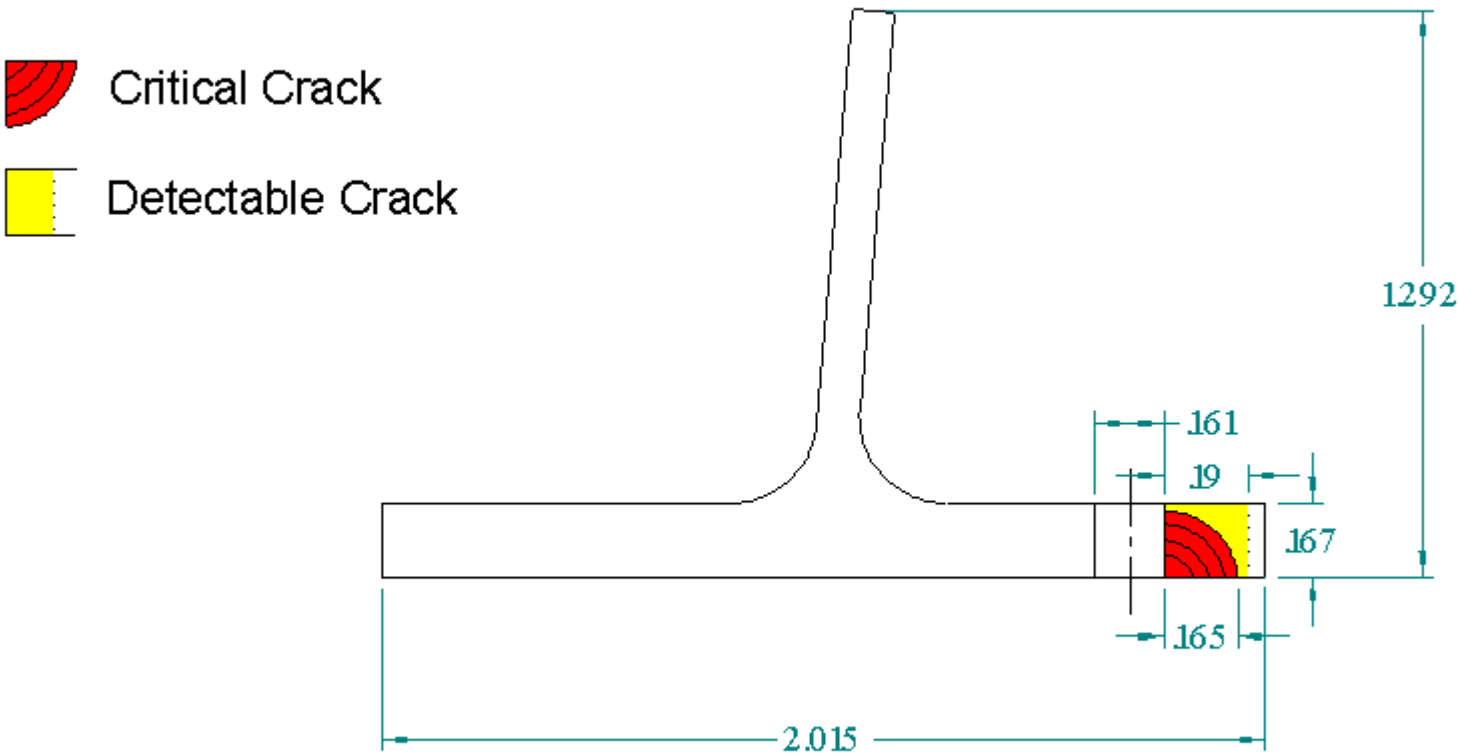
Cessna
A Textron Company

Crack Growth Analysis



Cessna
A Textron Company

Existing NDI Procedure



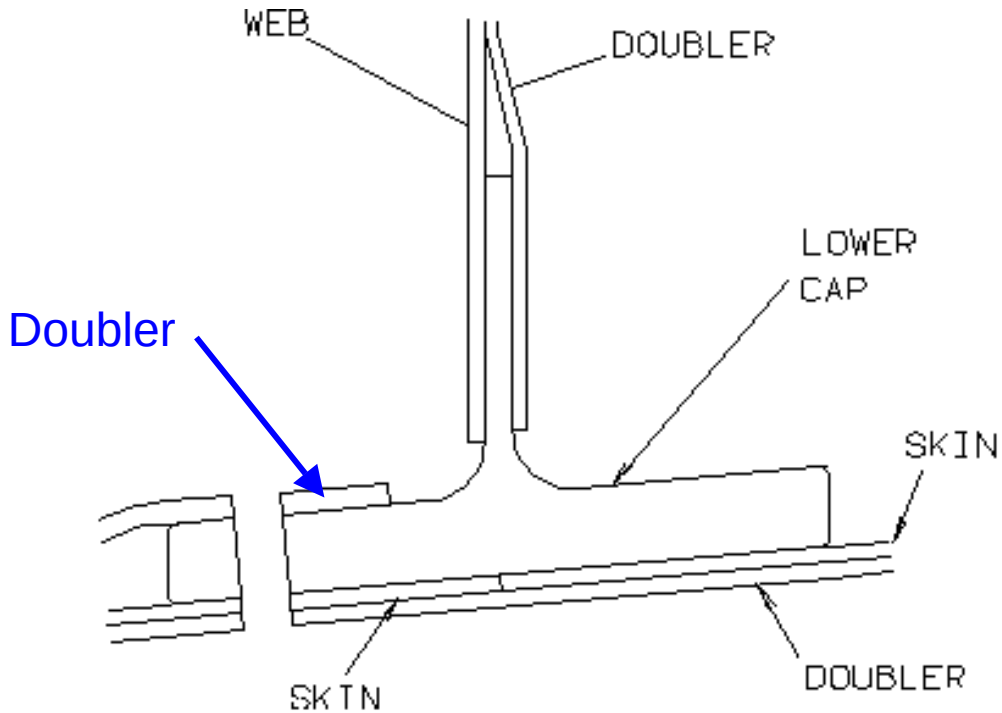
Cessna
A Textron Company

Existing NDI Procedure

- The eddy current procedure (per ME79-16 and AD 79-10-15) has been successful only once in finding a spar cap crack
  - Inspection was conducted by experienced Cessna NDI personnel
- Reliability of inspection is hampered since much of the main spar flange is covered by doublers

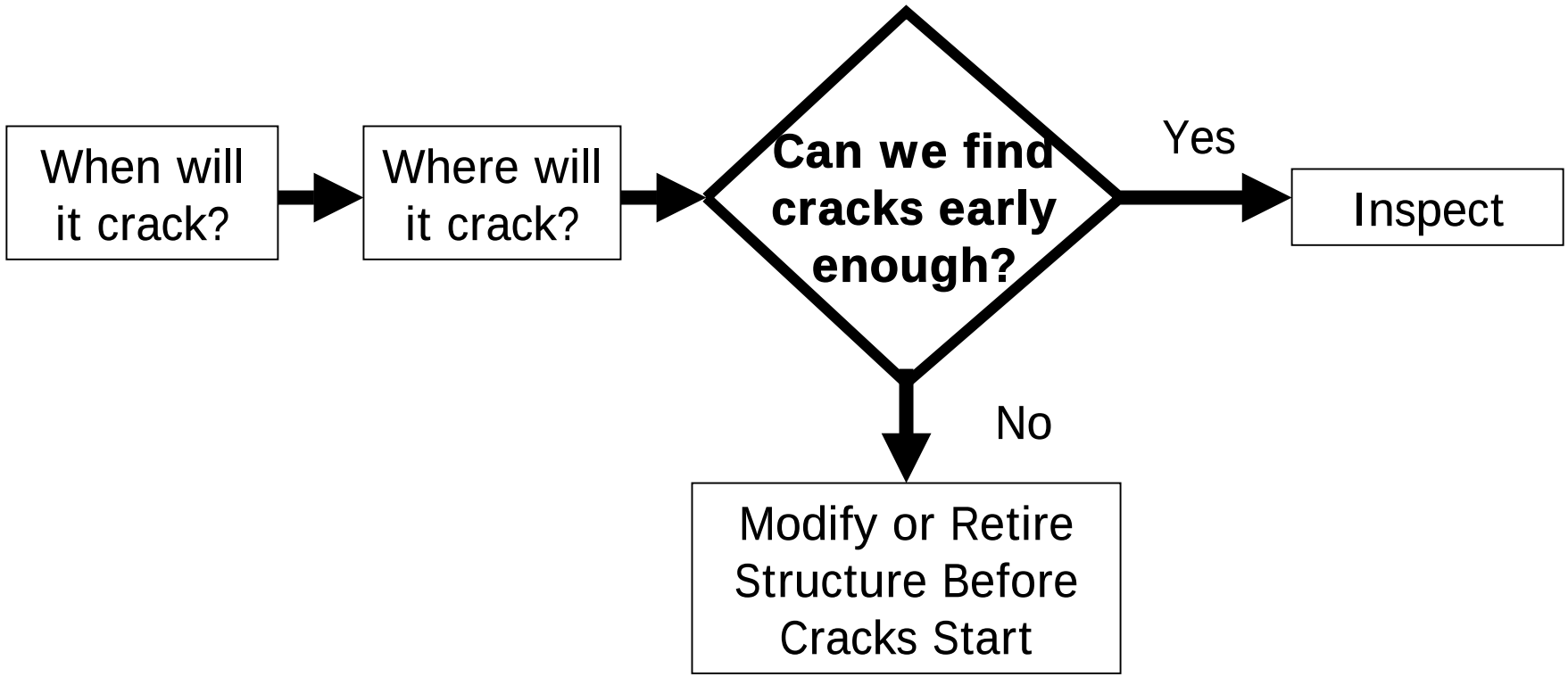
Cessna
A Textron Company

Doubler Over Spar Cap



Cessna
A Textron Company

Options For Controlling Fatigue



Cessna
A Textron Company

Alternate NDI Inspection?

- An alternative to low frequency surface eddy current is bolt hole eddy current
  - Will find a .08” crack, which is before wing loses ability to carry the required loads
  - Requires removal of about 175 rivets
  - Repetitive inspection is less than 400 hours
  - This method is destructive and impractical

Cessna
A Textron Company

Models 402C and 414A

- Cessna Service Bulletin MEB99-3 requires visual inspection every 100 hours for the Model 402C
  - Service bulletin intended as an immediate response to Model 402C accident
  - 100 hours based on analysis showing wing will retain its required strength for 600 hours after main spar cap failure
  - AD2000-23-01 issued
- Cessna Service Bulletin MEB00-7 requires visual inspection every 100 hours for the Model 414A
  - No AD issued in US, however foreign countries have issued an AD

Cessna
A Textron Company

Models 402C and 414A

- A diligent inspection of the spar should find a crack before the wing loses its ability to carry the required loads
- Potential for less than diligent inspections and FAA guidance material AC91-56B requires additional measures be taken to provide terminating actions

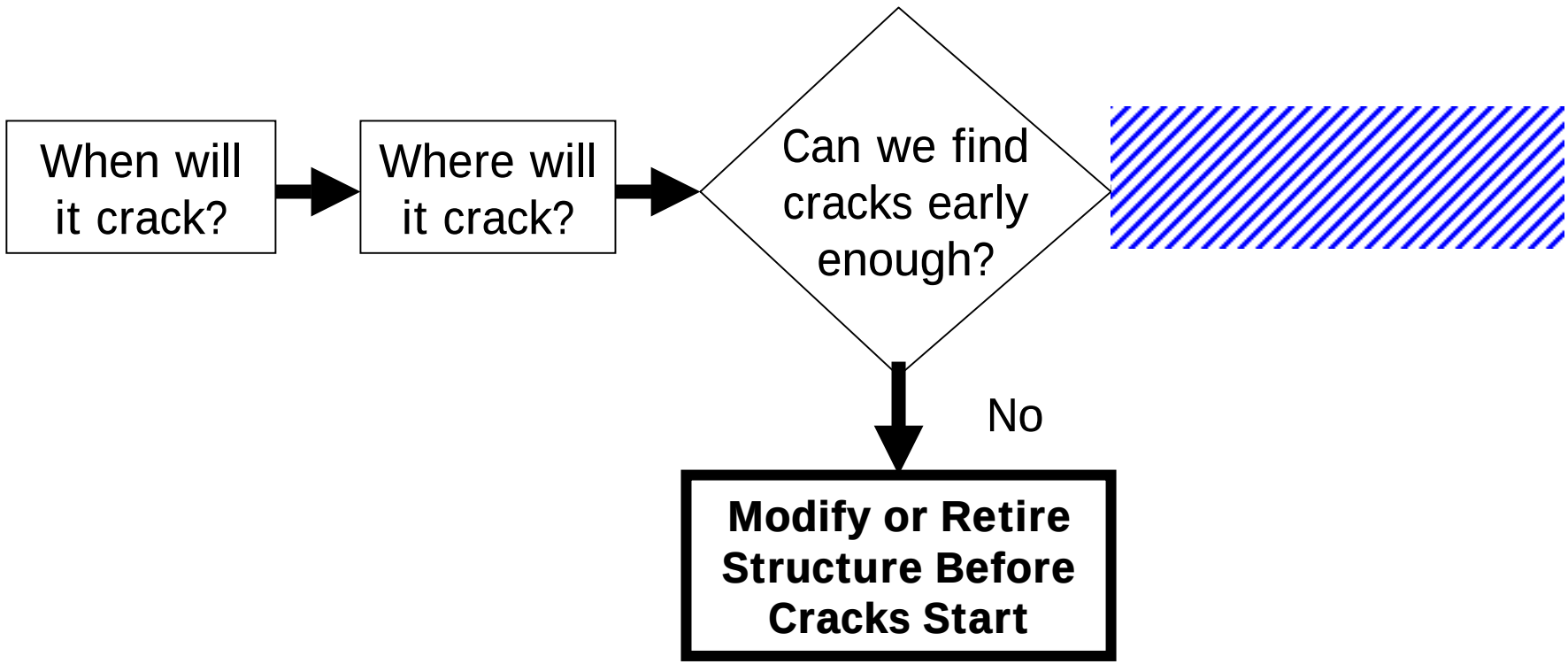
Cessna
A Textron Company

FAA Guidance

- FAA Advisory Circular AC91-56B, "Continuing Structural Integrity Program For Airplanes"
  - Requires airplane modification if cracking will have catastrophic consequences, and
  - NDI inspections will not reliably find cracks

Cessna
A Textron Company

Options For Controlling Fatigue



Cessna
A Textron Company

Retirement

- Australia CASA
  - Originally chose the life limit approach to control fatigue
    - Replace spar cap after one lifetime or modify wing with reinforcement strap
    - Retire entire airframe after two lifetimes
  - Retirement lives removed in 2000 if owner complies with Cessna SID Document

Cessna
A Textron Company

Retirement

- United Kingdom CAA
  - Also chose the life limit approach to control fatigue
    - Retire airframe after one lifetime
  - Retirement lives removed in 2003 if owner complies with Cessna SID Document
- CASA and CAA retirement lives based on original Cessna fatigue analyses
- Retirement is not the preferred option

Cessna
A Textron Company

CASA/CAA Life Limits

Model	Hours	Flights
401	8,200	12,600
402/402A/402B	8,200	12,600
402C	7,700 (CASA) 9,400 (CAA)	13,200
411	6,800	10,500
414A (1978, units 1-200)	6,500	5,900
414A (1979-1985)	13,700	12,500
414A (1978, units 1-200) With RAM winglets	3,300	3,000
414A (1979-1985) With RAM winglets	6,900	6,300

Cessna
A Textron Company

Agenda

- Airframe Design History
- Fatigue – General Concepts
- Analysis
- Fatigue Tests
- Field History
- NDI Options
- **Wing Modification Options**
- Conclusion

Cessna
A Textron Company

Wing Modification

- Four options were considered on how to modify the wing
  - Option 1: Cold-working spar cap fastener holes
    - Advantages
      - Significantly improves fatigue life at fastener holes
    - Disadvantages
      - Will not improve fatigue life if crack does not start from a fastener hole
      - At least one of the spar cap cracks in the field did not pass through a fastener hole
      - Ineffective and or detrimental if fastener hole is too close to the edge of the part

Cessna
A Textron Company

Wing Modification

- Option 2: Remove and replace spar cap
  - Advantages
    - Time for fatigue crack to develop is reset to zero for the spar cap
  - Disadvantages
    - Will require more fasteners to be removed than installation of wing spar reinforcement strap
    - Spar cap will need to be replaced more often (6,500 hours for 402) than the wing reinforcement strap inspection (20,000 hours)
    - Installation time and cost

Cessna
A Textron Company

Wing Modification

- Option 3: Shorter reinforcement strap
  - Advantages
    - It is less intrusive than Cessna recommended wing reinforcement strap
  - Disadvantages
    - During fatigue testing, cracks developed just outboard of the end of the strap
    - Installation time and cost

Cessna
A Textron Company

Wing Modification

- Option 4: Long reinforcement strap
  - Strap in MEB01-6, MEB01-7 and MEB02-5
  - Advantages
    - Provides reinforcement to all highly loaded areas
    - NDI inspections are not required for 20,000 hours for Model 402
  - Disadvantages
    - Installation time and cost

Cessna
A Textron Company

M400 Series SID/Strap

Airplane	SID Release Date	Strap Availability
401/402	Released	9/2001
402C	Released	6/2002
404	2005+	Not Required
411	Released	9/2001
414	Released	3/2003
414A	Released	6/2002
421	Released	3/2003
421C	Released	2004
425	2005+	7/2002
441	2005+	Not Required

Cessna
A Textron Company

M300 Series SID/Strap

Airplane	SID Release Date	Strap Availability
310 thru 310D	Released	2004+
310F thru 310K	2005+	2004+
310L thru 310N	2005+	2004+
310P thru 310Q	2005+	2004+
310R	2005+	2004+
320 (’62-’65)	Released	2004+
320 (’66-’68)	2005+	2004+
335	2005+	2004+
340	2005+	2004+

Cessna
A Textron Company

Agenda

- Airframe Design History
- Fatigue – General Concepts
- Analysis
- Fatigue Tests
- Field History
- NDI Options
- Wing Modification Options
- **Conclusion**

Cessna
A Textron Company

Conclusion

- Currently mandated inspection methods are inadequate to detect fatigue cracks in the wing spar before the wing can no longer carry the required loads
- This conclusion is based on analyses, testing and field data
- The wing spar reinforcement strap is necessary to address the continued airworthiness of these airplanes
- Failure to install the reinforcement strap or some other alternate means of compliance to achieve similar results, will increase the likelihood that a fatal accident will occur due to spar cap cracking